Proposal No. 22-2109
May 19, 1976

A PROPOSAL FOR

DEVELOPMENT OF TIME-DILUTION DREDGED MATERIAL BIOASSAY USING ZOOPLANKTON

Part I – Technical Proposal

In response to RFP No. DACW39-76-R-0025

to

Director
U. S. Army Engineer Waterways Experiment Station
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I. INTRODUCTION

Scientists in diverse research disciplines have produced much valuable basic and practical data from support of the U. S. Army Engineer Waterways Experiment Station (WES) through the Dredged Materials Research Program. The results of these studies are leading to better supervision of dredging activities in order to minimize or avoid negative environmental impacts. A major area of interest has been the effect of releasing possible toxicant materials from resuspended bottom deposits and the subsequent exposure of the indigenous biota. This problem is compounded in that often the areas to be dredged are also the recipients of sediments from heavily polluted waters. Bioassay as a tool to quantitate toxic effects offers an opportunity to provide some predictive capability in assessing environmental effects of dredging prior to the action.

This proposal is in reply to RFP No. DACW 39-76-R0025, for a simple, adaptable bioassay technique which can be used to evaluate the potential for toxicity that a proposed dredging activity may produce. The research has been done to establish the requirements for such a bioassay. Bioassay, zooplankton culture, the Elutriate Test, and the other aspects of previous research to be understood in formulating the best bioassay techniques will be discussed with emphasis on the problem areas which place constraints on formulating an Elutriate Bioassay.

Southwest Research Institute (SwRI) proposes to follow closely the tasks as set out in the request for proposals. These are introduced here with pertinent points for further discussion briefly mentioned. Task I, the literature review, has two major areas of work associated with it. First, the review of generally available published literature is well known to us and therefore that task is well in hand. Present research in zooplankton culture and bioassay techniques in this laboratory have assured an understanding of this information. Second, unpublished data and reports of the Waterways Experiment Station are expected to be especially significant in physical/chemical interactions of water and dredged materials (Johnson, 1974). The time-dilution factors to be included in the bioassay test for hopper, pipeline, and barge disposal techniques, used in open waters, should be available from these data. Continuing studies such as those of Brannon at the Environmental Effects Laboratory, WES, on long-term mass release of chemicals from dredged material will be carefully followed for most recent developments. A significant effort to review these studies with the WES personnel who helped develop the data is expected to be necessary.

Task II, formulation of procedures, should be well underway during visits to WES for review of unpublished data so that understanding of the proposed techniques will be assured between SwRI and WES. It is emphasized here that our understanding of the need of WES is for a simple yet reliable test which can be set up and administered by technical level personnel without comprehensive experience in bioassay work. Present research in this laboratory has reviewed the different published techniques for flow-through bioassay and several approaches to the stated problem are available. Options will be judged for several criteria including equipment availability, ease of maintenance, ease in testing, statistical validity of results, and adaptability to varying test organisms and conditions.

Task III, the procedure trials, is critical to the success of this program from several standpoints. SwRI proposes that while the simplified procedures formulated for manual publication are the most important product to be evaluated, several additional steps should be included in the evaluation procedure. For example, the bioassay apparatus and test organisms might be set up for a test with a standard elutriate according to the proposed technique for time-dilution exposure, but in addition a tracer material such as fluorescein dye might be added to the test water and monitored in the effluent by a fluorometer as a means of very accurate determination of the effectiveness of the dilution apparatus. Investigation of the effects on more than the species given in the RFP should be considered. Other similar forms are either in culture or have been used for studies in this laboratory, and we feel that they offer checks to the research program which will give better overall results to the sponsor. For instance, Acartia is known to be a relatively hardy copepod and effects which might not be demonstrated with it but attributable to the system design may show up when the procedure is tested with a more sensitive species. The statistical tests which might be formulated for the Procedures Manual could also be better tested if variability in responses was realized through wider species offerings. The use of reference toxicants in comparison to elutriates from dredged material also offers further "calibration" of the system during the testing phase. SwRI proposes the consideration of Rangia cuneata larvae as the principal molluscan test organism rather than Crassostrea. The rationale for this proposal is explained.

Task IV, preparation of the manual, is an area in which SwRI has a great deal of experience. Extensive editorial and publishing services are available in the Institute which will insure the most usable type of manual considering the stated need for a "cookbook". The proper blend of scientific information, evaluative techniques, and equipment requirements in an understandable format will be realized. SwRI recognizes that it is common to develop a "cookbook" which in fact is not adequate to the needs, often as a result of complication in instructions, overwriting, or too much explanation. Scientists have a tendency to try to document minutia instead of concepts in such efforts. A usable manual will be assured through review of the design produced by the scientific team by professional science writers.

II. LITERATURE REVIEW

A. Dredging in Perspective

The broad spectrum of potential environmental problems associated with hydraulic dredging has become one of the most noticeable if not the most controversial activity of man occurring in the nation's waterways. It is noticed by many and understood by few.

Dredging has been necessary for the development of many industrial sites, recreation areas, waste disposal areas, navigation, and sea commerce, as well as for the recovery of valuable minerals. For example, May (1973) stated that hydraulic dredging is of major importance to the commerce and economy of all coastal regions in the United States. Water transportation is dependent upon channel construction by the U. S. Army Corps of Engineers which currently dredges approximately 380 million cubic yards of material annually in the U. S. In conjunction with the construction and dredging of channels and waterways, there is also commercial dredging for shell, sand, gravel, and marl.

The major question that has now been raised is whether dredging and subsequent disposal of material moved can continue as they have in the past or should they be altered more to prevent any further ecological damage. Herbich and Schiller (1973) have listed eight possible environmental effects of dredging, four that are advantageous and four that are deleterious.

Advantageous effects:

1. Removal of polluted bottom sediments for storage and treatment.
2. Advantageous change in flow patterns.
3. Reoxygenation of sediments and the water column.
4. Resuspension of nutrients.

Deleterious effects:

1. Removal or burial of habitats.
2. Detrimental change in flow patterns.
3. Resuspension of polluted bottom sediments.
4. Formation of possible barriers to the movement of marine life.

Both advantageous and deleterious effects are the subject of current research in the Dredged Materials Research Program at WES. Emphasis on negative effects is of primary concern to the public. These adverse effects can result from the actual dredging itself and/or from the type of dredged material disposal: pipeline, hopper, or barge. Although dredging has had a long history, there were few published studies which attempted to identify the resultant environmental effects until the past few years. A brief review of some of the past studies helps to understand the various factors that influence both advantageous and deleterious effects, while at the same time leaving many questions unanswered.

Wilson (1950) studied the effects of shell dredging in Copano Bay, Texas. He found that turbidity (above background levels) from the dredge extended from 300 to 900 feet out and that actual material transport did not exceed 900 feet. He subjected oysters in the laboratory to very high concentrations of silt and concluded that this would be detrimental if continued for extended periods of time. Hellier and Kornicker (1963) studied sedimentation from a hydraulic channel dredge in Refish Bay, Texas. They reported that after 18 months, 22 to 27 centimeters of sediment deposition had occurred within one-half mile from the dredge. Other than this, they felt that dredge silting at greater distances was negligible. Another study on the dredging of an intracoastal channel near Redfish Bay by Odum and Wilson (1962) found that respiration exceeded photosynthetis in the dredge tailings, possibly as a result of the resuspension of organic matter. However, they hypothesized that in post-dredged areas, high production and dense grass growth were a result of the re-release of nutrients from the bottom sediments dredged. Other findings of Odum (1963) correlate with these of Odum and Wilson (1962).

Cronin et al. (1970) studied the gross physical and biological effects of overboard disposal on marine organisms, including zooplankton, in Chesapeake Bay. They found that fine sediments released as a semi-liquid by the dredge increased turbidity over an area of 1.5 to 1.9 square miles around the disposal site. However, suspended sediments in the top 10 feet of the water column were carried in a tide-related plume to a distance of 3 miles, but virtually disappeared within two hours after pumping ceased. They found no gross effects from dredging and disposal on phytoplankton, primary production, zooplankton, adult fish, or their eggs and larvae. They did find a reduction of about 65% in the benthic biomass at the disposal site.

O'Neal and Sceva (1971) concluded that open water disposal from a pipeline dredge produced little or no change in surface water quality. The chief visible effect was the turbidity plume created. Hopper dredges were concluded to have created little visible effect on the water quality. They also pointed out that the settling rate of sediments is more rapid in salt water than in fresh water and felt that the development of a healthy benthic community would be inhibited if the volatile solid content of a would-be dredged area was 10% or higher.

Gordon (1974) studied the dispersion of dredged material dumped into near-shore waters. He found from turbidity measurements that 99% of non-cohesive material of high silt content discharged from a hopper type scow in the presence of a tidal stream was transported to the bottom as a high-speed, turbulent jet. When 2000 cubic meters of dredged material is discharged into water 20 meters in depth, the resultant density surge carries less than 18% of the spoil outside a circle of 30-meter radius and essentially none beyond about 120 meters. Water column turbidity in the area of discharge contains less than 1% of the material discharged.

This overview of the types of results seen with various types of disposal techniques and locations gives an insight into the wide range of possible concentrations and elutriation of contaminants in dredged materials. The controversial biological effects of such disposal have not been discussed. The potential for significant biological damage exists with unwise disposal techniques.

Sites considered for future dredging and dredged material disposal will receive individual consideration in relation to ecological impacts according to Section 404 of Public Law 92-500. If adequate controls are to be established for dredging and disposal to lessen effects other than physical ones, then extensive laboratory testing should be initiated with elutriate technique bioassays conducted on representative organisms and selected sediments which would be subject to dredging. The development of an Elutriate Bioassay offers an expedient solution to the problem of quantifying potential damage.

B. The Elutriate Test

Research on the development of techniques to provide elutriates of the potential toxicants in dredged materials has received a significant amount of interest and attention during the DMRP (Lee and Plumb, 1974, Lee, Lopez and Mariani, 1975, and Lee, Lopez and Pimoni, 1975). SwRI proposes that the procedures of the Elutriate Test as it is presently designed are adequate for the purpose of the proposed research. Further questions to elaborate on the effectiveness of elutriation of all potential toxic agents under various conditions are the subjects of other research. Minor changes in the technique should have little influence on the applicability of properly formulated and tested bioassay techniques. For the purposes of this proposal, the review of the literature relative to potential release of toxicants will be focused on the research of Dr. G. Fred Lee and his students from which the most current knowledge of the problem has been gained. The importance to the development of a bioassay procedure is in the understanding of the various physical and chemical constraints which must be adhered to in order to assure that the test is reflective of reality or as close an approximation of it as can be realized in the laboratory.

The purpose of the Elutriate Test is to detect any significant release of chemical contaminants in dredged material. Briefly, it involves the mixing of a volume of sediment with four equal volumes of water from the disposal area and shaking for 30 minutes. This mixture is settled for one hour and either filtered or centrifuged as needed for further clarification of the elutriate. When the chemicals released in the elutriate exceed 1.5 times the amount in the starting elutriate water, the disposal of the dredged material is considered to warrant further investigation for possible toxicity. This simple technique has been devised as a standard because of its basic nature. The many factors which influence actual leaching of contaminant materials from the dredged material are well documented and include the following: chemical composition, solid-liquid ratio, time of contact, pH, dissolved oxygen concentration, agitation, particle size, handling of solids, characteristics of water and sediment, and solid-liquid separation (Lee and Plumb, 1974). In formulating and testing procedures for bioassay of zooplankton, adequate control and monitoring of these factors must be done. As further research shows other physical and chemical constraints, these should be evaluated for their effects in bioassay tests.

Several factors which are included in the list of parameters which influence the dissolution and release of contaminant materials from dredged materials require special treatment in bioassay testing of an elutriate. Dissolved oxygen presence and concentration strongly regulates the chemical form, solubility, and mobility of several constituents. The time-dilution models formulated for the elutriate during bioassay need to take into account changes in dissolved oxygen likely to be seen in actual disposal practice. Where disposal practices might reduce dissolved oxygen and jeopardize survival of test organisms, reasonable judgments must be made on the zone of natural mixing which might provide minimal amounts of available oxygen yet approximate the most serious possible effects of overboard disposal. Similarly, where reoxygenation of reduced deposits may significantly increase nutrient availability, forms such as oyster larvae which can utilize inorganic nutrients and some available amino acids directly may be significantly aided in development. Tests should take into account the possibility of such influences. The significance of the redox interactions of dredged material and bioassay test organisms has been discussed by Lee and Plumb (1974) who point out the need for better control of time-dilution in elutriate bioassays. Their discussion of other research explains that previously seen mortalities during dredged material bioassays was likely caused by an oxygen reduction due to a high oxygen demand in the dredged material.

Several factors must be considered when estuarine waters receive dredged material. This results from the changeability of chemical form and reaction characteristics which accompanies changes in salinity. The changing of salts content produces changes in pH and osmolality, which may or may not influence plankton survivability and which may or may not require controlling measures during bioassay tests. Adequate consideration of these problems and monitoring of their effects during the test phase are necessary in order to formulate the best bioassay technique.

SwRI proposes that, given proper consideration for the types of problems cited and other similar influencing characteristics of the

Elutriate Test, elutriate prepared from the basic methodology is adequate for bioassay testing. The drawbacks to the success of the test in depicting all possible elutriation of contaminants are well documented and suitable allowances can be made. The major advantage of the technique for present research is the simplicity in arriving at an elutriate product useful for testing. Though it is empirical, the Elutriate Test is better than a bulk-analysis approach to regulating dredged material disposal because it recognizes that synthetic mixtures cannot be prepared to simulate adequately all characteristics of estuarine waters that affect the results of bioassay tests.

C. Bioassay Techniques

Bioassay techniques have a long history and have been used for many varied applications. As the demand for water usage increases, so also does the need for information relating to the environmental impact of complex wastewater discharges. This current concern has greatly increased the use of aquatic bioassays. Many researchers have used the concept of controlled exposure of organisms to a possible outside factor, but only in recent years has any degree of standardization been sought. The following discussion will briefly outline the significant recent developments in bioassay and show how the flow-through technology is applicable to the proposed research.

Several reviews of bioassay use and techniques have been written. Tarzwell (1971) has discussed the history of bioassay and the direction that he proposed as Director of the National Marine Water Quality Laboratory. A thorough description of the information needed for the protection of aquatic life was also described by Tarzwell (1962a, 1962b, 1966). Sprague (1969, 1970, 1971) published an excellent series of reviews on (1) Bioassay methods for acute toxicity, (2) Utilizing and applying bioassay results, and (3) Sublethal effects and "safe" concentrations.

Mount and Brungs (1967) made the most significant single step in contemporary bioassay techniques when they described a simplified, precise, and reliable proportional delivery system for water supplies to aquatic species. This equipment was rapidly utilized by many workers in establishing flow-through systems for bioassays and is recognized by the EPA as the standard design (EPA-660/3-75-009, 1975).

Diluter systems have an adaptability to a variety of test species and toxicant concentrations as well as long-term dependability and fail-safe characteristics. Several workers have made additional modifications for special purposes or reliability (Freeman, 1971; Bengtsson, 1972; Granmo and Kollberg, 1972; Abram, 1973; Lichatowich et al., 1973; Shumway and Palensky, 1973; Sprague, 1973; Schimmel, Hansen, and Forester, 1974). DeFoe (1975) described a multichannel toxicant injection system for flow-through bioassays which employs falling water from a series of water-metering cells to activate a series of mechanical syringe injectors. Riley (1975) describes the proportional diluter designed by Wuerthle and Riley as a modification of the Michigan diluter (Wuerthle et al., 1973). Brungs and Mount (1970) remodified the proportional diluter of 1967 to develop a system which is free from clogging caused by suspended solids, snails, etc. Benoit and Puglisi (1973) built an effective flow splitting chamber for diluters. This simple piece of equipment has had significant utility in assuring precise dosages for duplicate test animals during bioassay tests. An electro-mechanical device was constructed by Bahner and Nimmo (1975) to monitor and dilute seawater to constant salinity for flow-through bioassays. Brenniman et al. (1976) developed a new continuous flow bioassay method that is capable of adequately handling highly volatile and evaporative hydrocarbons. This system prevents evaporation of volatile toxicants, puts slightly soluble hydrocarbons into solution, and renews the volume in the test containers fast enough to keep pace with evaporation of toxic hydrocarbons.

McAllister *et al.* (1972) describes a simplified device for metering chemicals in intermittent-flow bioassays. This modification is unique in that it has no moving parts, minimizes evaporation, provides sufficiently accurate delivery of small volumes of solutions, and is inexpensive. A saltwater flow-through bioassay method with controlled temperature and salinity was developed by Bahner *et al.* (1975). Other modifications have been made which further alter the bioassay and diluter design as necessary for test organism size and various conditions of water salinity, temperature, and quality.

The status of bioassay as a tool for research has reached the point of passing from the individualized research worker or laboratory phase and is entering the standardization phase. As the best of the flowthrough equipment types become established in a number of laboratories, the correlation between test results will be improved. The significance of this for the proposed research is that a greater number of researchers and locations over the country will be ready to do the elutriate bioassays which will be necessary for describing potential dredging effects. The one step remaining is to provide a standard procedure to be followed by all, so that different laboratories can obtain comparable results. This will be accomplished by the "cookbook" procedures developed by the program outlined in this proposal.

Recently, federal legislation was promulgated for regulating effluent toxicity standards to be applied uniformly nationwide for each type of pollutant. According to Davis and Hoos (1974), the inclusion of reference toxicant tests would improve the quality of test procedures for comparative purposes. At present, use of reference toxicants for standardization of bioassay appears rare and has only been applied to testing oil dispersants (LaRoche *et al.*, 1970), pesticides (Marking, 1966), and in a special study by Davis and Hoos (1974). They included seven government and private British Columbian laboratories in a special effort toward bioassay standardization.

SwRI proposes that as extra control measures for the physical/ chemical aspects of the Elutriate Bioassay and extra test species may be necessary, the use of a standard reference toxicant be included in the test phase of the research. The nature of such a toxicant could be decided during the test formulation phase and reflect a potential problem chemical from dredged material or be a completely different material with primary utility in assessing the accuracy of statistical procedures used to verify Elutriate Bioassay procedures.

D. Zooplankton Bioassay

A review of the literature indicates that little has been done using zooplankton for bioassay of dredged material or other pollutants. The most recent comprehensive bioassay paper is the Workshop on Marine Bioassay (1974). This describes a "cookbook" method for culturing and assaying Acartia tonsa (Gentile, et al., 1974) which can be adapted for other organisms. The method is adequate for consideration in the proposed research and will be used as the standard technique for purposes of the present discussion.

Most desirable assays are conducted using animals of standard age (Gentile et al., 1974) as different life stages are affected by toxicants in different ways and to varying degrees. Different stages of a species may be tested, however, to supply information on the effects of toxins on the life cycle. Standard age bioassays require a stock culture of whatever organism is to be tested. The species proposed for the present research have culture requirements ranging from easy to extremely difficult. Some animals, such as Daphnia, can be bought from biological supply houses in suitable shape for testing. Others, including oysters, require extensive holding aquaria and food culture facilities in order to reproduce significant phases of the life history. Depending on time and resources, different methods of culture are available. Static culture facilities are inexpensive but require intensive handling which may fail to exclude toxicants. Gentile *et al.* (1974) describe a static system. A recirculating system is more expensive but requires less manpower for operation and is more efficient. Recirculating systems are described by Gentile *et al.* (1974), Zilloux (1969), and Zillioux and Lackie (1970). In an effort to standardize bioassays, Cairns (1969) suggested using an artificial water as even "unpolluted" natural water may contain trace contaminants that are not detected by normal tests but which could alter results. Research in developing zooplankton flow-through bioassay in this laboratory is designed to use artificial seawater. Water from several dredging sites could pose problems in Elutriate Bioassays by having different elements present which would invalidate comparisons or make correlations of bioassays from different areas difficult.

Although less desirable, organisms collected from nature can also be used. In this case, it is difficult to be assured of standard age or of freedom from any effects from being transferred to artificial conditions. To use a "wild" strain, it is necessary to bring specimens into the laboratory and acclimate them for several days to a constant temperature and salinity. This acclimation should be done in artificial water to remove the possibility of exposure to contaminants in the natural water which may influence tests. Controls with natural seawater may be set up to determine if effects differ in artificial or natural water. It is possible that contaminants in the natural water would react differently during Elutriate Bioassay causing effects that would not be seen using artificial water. The complexity of potential problems shown in this discussion is reason for proposing simplification in test procedure wherever possible.

The conclusion to be drawn from this discussion of the status of the various important parameters describing inputs to the design of the Elutriate Bioassay is that the research has been done to adequately show directions in technique development and areas where problems are to be anticipated. The variables are well documented and the consistencies described.

III. TECHNICAL APPROACH

A. Schedule of Activities

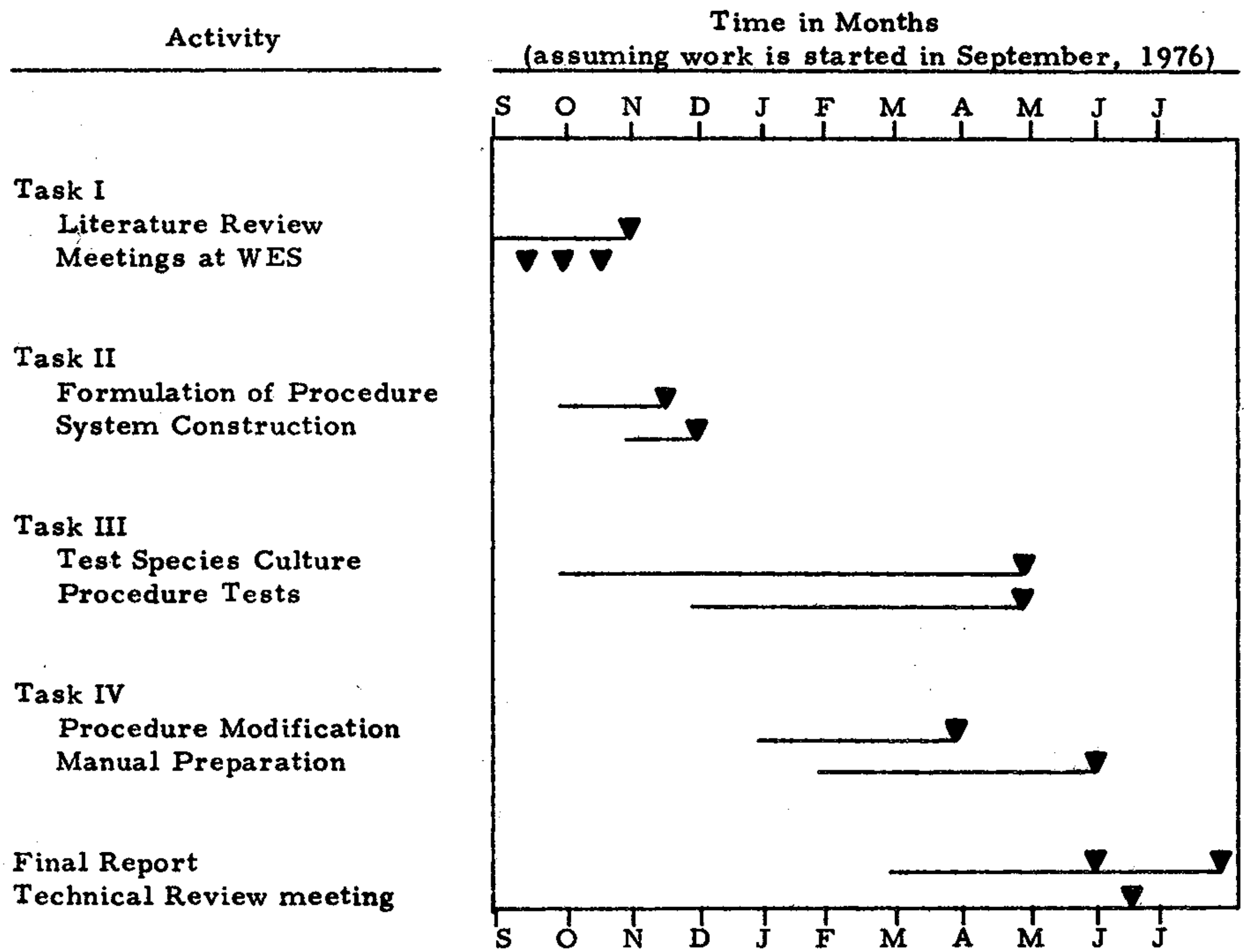
SwRI proposes that research for this program be instituted in September, 1976, as the earliest practical date after proposal consideration and contract negotiations. Several factors favor this time. Most significant is the availability of several suitable test organisms from wild stocks for the establishment of cultures of test animals. The oyster is the most difficult of the test organisms to procure and maintain, and oysters will reach maximum condition for laboratory use prior to spawning in late winter and early spring in Gulf coast waters. *Rangia* larvae are available both in the fall and spring, should research be initiated soon enough to use fall spawners. *Acartia* are readily available in the fall for start of cultures, and generally suitable weather and water conditions during the late summer and early fall make collection of other copepods easy. The internal research program recently initiated by SwRI-Houston to establish flow-through bioassay systems for nekton and zooplankton will be in its final phases during this period, and the results of this research will have a favorable bearing on evaluation of bioassay systems for dredged material elutriate.

Figure 1 gives the schedule in outline form with report dates and other important milestones emphasized.

B. Task I - Literature Review

From ongoing research in bioassay, especially with zooplankton organisms, most of the pertinent published literature is already available to SwRI. This phase of the research should require a minimum effort and time for completion. Ample library facilities and search aids are available through the SwRI Thomas Baker Slick Memorial Library in San Antonio, the biology collection at SwRI-Houston, and various local universities with which we have working arrangements. These include Rice University, the University of Houston, and Texas A&M University.

Figure 1. Schedule of Activities



Standard search techniques will be used to complete this phase of the review. Of more significant concern in planning is the need for review of unpublished WES data and the recent reports from WES not yet in refereed journals. Since this information is expected to offer important assistance for planning, significant effort in examination and evaluation is proposed at Vicksburg. The literature review period should be completed within two months of initiation of the project, including three trips of two or three days to WES for gathering of material there and discussion of findings with WES personnel. The result of such a plan will be to introduce Task II during the final stages of Task I.

Bioassay techniques and modifications which show the best promise for use with dredged material elutriates will be compiled and evaluated by the three professional staff members most closely associated with the proposed research. The principal investigator will coordinate the efforts of the zooplankton specialist and bioassay specialist during review meetings for the purpose of discussing various techniques. A set of criteria will be developed including equipment availability, ease of maintenance, ease in testing, statistical tests necessary, and adaptability which will be applied to each technique. Since practicality is a primary requirement for the manual procedure, such aspects will be considered more than concerns for physical control of the chemical state or availability of potential toxicants. Adequate determination of such influences during the testing phase will guarantee that the final test will fall within accepted bounds for practical results as opposed to detailed research requirements.

An important part of this phase of the research is the complete understanding of differences which different disposal techniques may impose in the way bioassay procedures are set up. For instance, the sudden massive discharge from a hopper dredge produces significantly different dispersion than the continual discharge from a pipeline, and barge disposal results may vary widely according to the type of nozzle regulating the flow. While the mathematics describing the physical action involved in each type of disposal may be quite complicated, it is the translation of this detail into a time-dilution scheme which can have practical application which will be of primary concern to the literature evaluation team. SwRI has ample expertise in the field of hydraulics modeling; therefore, the problem of translating physical descriptions of disposal dispersion into biological tests of the dispersants should be minimized.

C. Task II - Formulation of Procedure

This task will be initiated during the literature review phase as evaluation of recent research indicates important areas to incorporate into the design. It is expected that preliminary design can be finished within two months after the project is initiated. This would include discussions with WES personnel during trips for literature gathering to resolve particular points of interest and constraints in control of physical conditions which would cause changes in present bioassay procedures. Because design will be done to minimize material acquisition problems and test setups and because SwRI is presently doing similar studies, test assembly should be accomplished quickly. The third phase of the research should begin by the end of the third month.

1. Establishment of the Time-Dilution Models

It is the understanding of SwRI that the needs of WES require the development of time-dilution models for the dispersion and fate of dredged materials which will be applicable to establishment of systems used to test organisms as a bioassay. It is inherent in this process that a substantial simplification of the mathematical models for the physical description of the fate of dredged materials will be needed. Two reasons favor the ability of the SwRI-Houston research group to do this phase of the research. First, an ongoing association with Sandia Laboratories, Inc., Albuquerque, NM, has produced a model of the dynamics of heavy metals in a coastal estuary which has been studied by SwRI for over three years (Wayland _et al._, 1975). The inputs to this model included consideration of several compartments of the estuarine ecosystem, and the interplay between mathematical modeler and biologists supplying the factual data for the program assured understanding of the problems of making usable models or making use of existing models, either conceptual or mathematical. Second, significant experience in both experimental and analytical modeling has been gained at SwRI-San Antonio under the direction of Dr. R. L. Bass, Manager, Hydro-Mechanical Systems, Department of Mechanical Sciences. He is expected to bring his experience to bear in evaluating the research available through WES on modeling of dilution of dredged materials. This will be accomplished by meetings with SwRI personnel in Houston to examine WES and other data, formulate the basic time-dilution schemes to be the target of bioassay equipment, and then present these concepts to WES personnel in a meeting during the third month for finalization of plans prior to the testing procedure.

2. Bioassay Design

Current research by SwRI is directed toward developing the most useful flow-through bioassay systems, with application in two areas. The first is a system which can be used with larger fish and crustacean species and therefore represents more conventional designs. The second system is being specially designed to use zooplankton as test organisms. The purpose of this internally sponsored research is the development of the best technology available for research with zooplankton as test organisms in laboratory bioassay work. Therefore, the lessons learned are very appropriate to the design of a similar system with time-dilution of the influent as a primary research goal.

Simplicity in design can be arrived at in two ways. It can be realized through assembly and use of readily available equipment, though not necessarily inexpensive equipment, or, it can be realized through the custom building of specialized equipment with basic simplicity inherent in inexpensive glassware, gravity flow diluters, and volumetric controls for time-dilution. The first approach is felt to be the most advantageous by this research group for the needs of the ultimate users of the bioassay manual. By designating off-the-shelf equipment and a minimum of assembly and construction details, greater standardization in systems will be realized. The zooplankton flow-through bioassay being developed in this laboratory includes standard respirometer culture flasks of 50 to 150 ml as test chambers, with flow-through accomplished by peristaltic pumps. Such a system is expected to be small enough to fit into a standard BOD chamber or similar controlled environment cabinet, thereby affording potential for additional control of environmental conditions. Since the system employs closed influent and effluent systems, dissolved oxygen in the test water can be accurately regulated at input and monitored in the chamber and output. Similar records of pH, hardness, salinity, Kjeldahl nitrogen, and the like can also be obtained. Examination of the test organisms is accomplished by use of an inverted stereomicroscope mounted on a swing arm which allows observation of the culture without removing it from an on-line status. For a dredged material elutriate bioassay, death of the test organisms may be used as a simple criterion for effect. Other types of long-term chronic effects will be studied in this laboratory for their resultant retardation in development of larval forms, failure of eggs, slow growth, or population changes.

The particular problem of time-dilution of the elutriate used in testing can be approached from two basic types of design schemes. Both use flow-through bioassay technology as the most practical way of subjecting test organisms to the elutriate. The first scheme would be to mix elutriate and diffusion water in the test chamber and use variation in rates of introduction and subsequent mixing and flushing to approximate the time-dilution model of actual disposal practices. Such a system could approximate the chemical changes possible in contaminants associated with disposal and immediately prior to contact with organisms in the water column. This scheme would also lend itself well to mechanical control of introduction of the test water to the test chamber with pump systems and electronic control of delivery rate. A second scheme would be to initiate the test with a premixture of the most contaminated elutriate/receiving water mix predicted by the time-dilution scheme and then use flow-through dilution to approximate natural processes. This method could be used with a much simpler system using gravity flow diluters and a minimum of test hardware. Each design has certain advantages that will be considered.

3. Control Operations for Bioassay Design

Several techniques will be briefly mentioned as potential monitoring devices for the efficiency of the bioassay system designed in regulating the time-dilution procedure and other environmental conditions for test organisms. The simplest standard technique for determining flow-through characteristics and effluent content of test ingredients will consist of a preliminary run of all hardware in the system with inputs of known concentration of simple salt water. The effectiveness of dilution and flow-through speed can be checked by conductivity meter or titration for the concentrations of the various input and outflow streams. Another potential method of making similar determinations with test organisms in place is to use a dye and fluorometer in the effluent streams to determine concentrations. Similarly, the fluorometer can be used to determine algal concentrations in input and outflow streams and by difference used to determine the effectiveness of feeding by test organisms. Such procedural testing could possibly show sublethal effects of test elutriates by causing specimens to stop feeding.

We have previously made reference to the use of standard toxicants for evaluation of the bioassay setup. Such standards should be used routinely in the testing phase to set up characteristics of the bioassay system and the tested time-dilution schemes for each test species. By using well known toxicants with a simple response effect, the variances needed to be established for statistical testing of the method and the statistical methodology will be more easily accomplished.

According to accepted procedures, all bioassay determinations during the experimental phase will include control chambers with test organisms in addition to the test chambers.

D. Task III - Procedure Testing

SwRI expects that the various aspects of culturing test organisms, literature review, and system design will lead to initiation of procedural testing by the end of the third month. Because fewer problems are expected with culture of *Acartia* and similar organisms for testing, it is proposed that tests can begin with the copepods. The RFP does not specifically list procedural testing to be done with *Daphnia*, but SwRI proposes that research with this organism begin shortly after copepod studies. The ease of *Daphnia* culture and its applicability to testing plus the added information from research with a freshwater species make the extra research worthwhile. It may be suitable to limit *Daphnia* bioassays to only a single time-dilution scheme since it would be used primarily for setting standards of variance in response rather than manual procedures for freshwater Elutriate Bioassay. Studies with molluscan larvae, either oysters or *Rangia* clams, should begin only after initial tests with more hardy forms are successful. This will give ample time for successful collection of spawning individuals and development of the capability of producing viable larvae as needed. The scheduled outline for project initiation in September will maximize the potential for readily procuring clams or oysters in good spawning condition.

1. Elutriate Preparation

Initial studies for testing of the various organisms should follow closely the standard procedures in preparation of the elutriate. Since flow-through and dilution of some kind will most probably be necessary in testing, a greater volume of elutriate will be necessary than for research on chemical constituent determinations and other physical determinations as in the past. SwRI proposes that large containers be adapted from commercially available fiber glass septic tanks for mixing purposes. Two-hundred-gallon vats would be equipped with mechanical stirrers or pumps with the capacity for mixing relatively large volumes. The stirring time may need to be extended in order to better approximate the results with smaller, high speed stirrers, and other precautions to approximate standard conditions may be needed. For instance, it may be appropriate to overlay the mixing vat with a layer of nitrogen as a measure to avoid too much oxygenation, or covering may be necessary to reduce illumination.

2. Chemical Analysis for Contaminants

The technology of identifying and quantifying the various chemical contaminants which are of importance in the elutriate prepared for bioassay testing is not discussed in detail in this proposal. The techniques are well developed and a part of several ongoing studies by SwRI. The Analytical and Biochemistry Section, Division of Chemistry and Chemical Engineering, SwRI-San Antonio, under the direction of Dr. Donald E. Johnson, has significant experience in determining constituent chemicals of a potentially toxic nature from a wide range of carriers and including the polychlorinated biphenyls, chlorinated hydrocarbons, heavy metals, and petroleum hydrocarbons indicated in the RFP. Routine analysis of such compounds uses the most contemporary GC/MS/Computer spectrophotometer combination for maximum efficiency and accuracy in determinations of a wide range of compounds and AA spectrophotometry for heavy metals. Because large numbers of determinations of the type needed are routinely done, expense in determinations is reduced and results can be realized for comparison with biological data on a short-term basis. Reports for studies presently being done in conjunction with SwRI-Houston are routinely completed within one month. Because of these activities, the necessary techniques for closely following the contents of the elutriate and the comparison of quantities from different batches and from different elutriate preparation techniques are readily available.

The extent to which chemical testing of elutriate preparations will be done should be thoroughly discussed and decided during initial phases of the research. At present, SwRI proposes that discussions with district or regional Engineers offices during the planning phases of the research will indicate areas where dredging activities are likely to be occurring during the period of bioassay testing and which of these areas has been previously determined to be heavily contaminated. This approach will avoid unnecessarily expensive screening of potential dredge sites for the pesticides, heavy metals, PCB's, and petroleum hydrocarbons present. Such screening activities are several times as resource-demanding as determinations of constituents in areas where contaminants have been identified previously.

Discussions with Mr. Victor Keesecker, Operations Division, Galveston District Office, USACE, indicated that the scheduled dredging operations for the Galveston, Texas, area includes several locations with potential deposits of heavily contaminated material. The GIWW is scheduled for maintenance work from Texas City to Freeport during early 1977. This activity will include open water disposal and will be in progress during a favorable time for research during the proposed program. At present, the only areas in the Galveston District which have been examined for the Elutriate Test are the developments in the Galveston Port area for which disposal was by hopper dredge in the open Gulf of Mexico. This activity has already occurred and is being studied under present WES research by a local university group. Data from these studies may be appropriate as background information for use in the bioassay testing phase.

Depending on the number of test organisms and bioassay schemes agreed on by WES and SwRI, the amount of chemical determinations to be done in the testing phase will vary. SwRI will process for identification purposes anywhere from ten to fifty samples at the same cost for the determinations of normally determined contaminants in the four classes necessary for the project. For the purposes of this proposal, costs have been calculated for 20 determinations of total important constituents from elutriates prepared prior to bioassay testing. The extent of determination effort will be the subject of scrutiny and understanding during discussion sessions between WES and SwRI prior to setting the analysis scheme.

3. Test Organisms

Zooplankters to be used in tests of the bioassay procedure formulated should fulfill two requirements. They should be representative of the types of organisms likely to be present in the areas where dredging activities will be going on and they should represent species which can be readily collected and cultured in the laboratory or acclimated to laboratory conditions. The types given in the RFP, *Acartia*, *Daphnia*, and *Crassostrea* larvae, meet these requirements; however, SwRI proposes that other forms be considered during testing and that a more suitable species than the oyster may be available for larval tests.

Daphnia pulex are well established in many laboratories and represent probably the most cultured freshwater crustacean for fish food, teaching laboratories, and general studies of freshwater zooplankton. While SwRI does not have them in culture at present, no unusual difficulties are expected in establishing a supply since Daphnia can be purchased from biological supply houses. These may be more or less susceptible to toxins than naturally occurring strains. Most cladocerans are rather hardy; therefore, a number of species may be amenable to culture and testing. In the area of our continuing field activities, Moina sp. is a very abundant cladoceran and could be easily collected for tests in our laboratory for comparison with Daphnia. Such a program would evaluate the most likely freshwater species for the manual and provide comparative data for another form similar in requirements. De Coursey and Vernberg (1975) cultured Daphnia pulex on hard-boiled egg yolk. Since Moina is in the same family and has similar ecological requirements, it could probably be cultured using the same method.

The estuarine copepod, Acartia, has been successfully cultured in this laboratory and others (Gentile et al., 1974). Its requirements are fairly well known and it is expected to be a very useful organism for bioassay tests over a varying range of salinity and water conditions.

It is an easily maintained organism, having been reported in culture up to 14 months (Zillioux and Lackie, 1970) and occurs over wide salinity ranges. It is a fast generating, constantly reproducing species, the average life cycle (egg to death) being 30 days at 20°C (Gentile et al., 1974). A. tonsa females are capable of producing more than 30 eggs/female/day when fed the proper food ration (Wilson and Parrish, 1971). With this species, a culture could be established and tests started within 30 days. Because of the wide environmental tolerances of this zooplankter, however, it is possible that it would be hardy enough to survive the most severe elutriate tests. While Acartia is recommended as the best copepod species to be evaluated, we have also acclimated marine forms collected from blue water areas 50 miles offshore in the Gulf of Mexico. Such varieties may offer more sensitivity, for use in evaluating dredging procedures in high salinity areas if needed. *Temore stylifera*, a calanoid, and *Oncea* sp., a cyclopoid, were dominant members in samples recovered and maintained. They were successfully cultured and bred in the laboratory by Neunes and Pongalini (1965); therefore, the techniques are known for maintaining them for tests which might be compared with the results from *Acartia* bioassays. Other estuarine examples for possible culture and testing could be *Pseudodiaptomus coronatus*, a calanoid, or *Oithona colcarva*, a cyclopoid. SwRI proposes testing be done on at least one other more sensitive species.

Acartia culture in this laboratory has used simple equipment consisting of standard aquaria, filters, artificial sea water, and several species of phytoplankton as food. The primary requirement for successful culture is cleanliness and timely monitoring of water conditions. Further work of the type proposed would require a recirculating system along the lines of the one described by Zillioux (1969) and Zillioux and Lackie (1970). With this system, *Acartia* have been maintained up to 14 months.

Larvae of the oyster, *Crassostrea virginica*, have been the subject of much research during the history of development of the oyster as the standard research animal for midsalinity estuarine areas. The difficulties in spawning, maintaining, and successful maturation of spat in the laboratory are well established. It is possible through adequate controls to have *C. virginica* larvae available during much of the year on the Atlantic and Gulf coasts. Similar availability exists with the large Japanese oyster *C. gigas* on the Pacific coast where much research has been done in recent years. However, it is important to point out here that the successful spawning and rearing of oyster larvae requires very stringent controls, and husbandry involves a great deal of experience as well as scientific ability (Epifanio *et al.*, 1976). Because of these culture difficulties, SwRI proposes that embryos and larvae of the brackish water clam, *Rangia cuneata*, be considered as the primary larval form to be investigated during Task II of the research.

Hopkins, Anderson and Horvath (1973) under contract to WES considered *Rangia* as an ecological indicator form for changes of salinity in estuaries. Research done during that project and continued in Bedinger (1974) show that the conditions necessary for culturing *Rangia* larvae are not nearly as stringent in temperature, salinity, water cleanliness, or food sources as the requirements for oysters. Internally sponsored research is continuing in our laboratory at present with particular studies directed toward delineating regimes necessary for successful rearing of *Rangia*.

Several reasons can be given for proposing *Rangia* larvae over *Crassostrea* larvae. First, the natural spawning cycle of the clam has been shown to extend over a biseasonal cycle in the south with larvae available during both spring and fall (Bedinger, 1974) and with larvae available during the summer further up the Atlantic coast (Peddicord, 1973). The salinity requirements for maintenance of spawning clams range from nearly freshwater conditions to above oceanic salinities with optima between about five and twenty-five parts per thousand. Spawning may be initiated by salinity shock, either up or down from these optima. Salinities can be changed drastically up or down once shelled veligers are produced from spawn. Therefore, the test organism is adaptable over a wider range of salinities than the oysters. The laboratory techniques required for fertilization and culture have been shown in this laboratory to be much less demanding than for oysters. An untrained technician can have successful results much more quickly than if he were attempting to rear oysters. This is important for the application of the ultimate "cookbook" tests in actual practice. While Rangias are not found on the West Coast, they are widespread from Mexico to the Chesapeake Bay region. It is in these areas that most dredging is likely to be occurring. Pacific coast sites such as the Columbia River mouth where significant dredging might be anticipated have a wide diversity of molluscan and other invertebrate larvae such as urchins which are well established as laboratory test animals. In long-term tests which might be done during the evaluation phase, Rangia would have the added advantage of not becoming attached to the substrate such as oysters would, but would settle on about the seventh day to become small clams though quite capable of both swimming and crawling movement for a considerable period of time. The food requirements for oyster larvae are well documented and relatively stringent for proper response. Rangia perform well with a wide variety of readily available algal food sources. While SwRI has the capability of providing both oyster and Rangia larvae, we propose that most testing be done with the clam and that oysters be used only as additional data are needed and as time and resources permit.

4. Phytoplankton Culture

A mixture of *Skeletonema costatum*, *Thalassiosira pseudonana*, *Isochrysis galbana*, and *Rhodomanas baltica* has been used successfully (Gentile *et al.*, 1974) as food for oceanic copepods. *Tetraselmus chui* has been used in feeding *Acartia* in this laboratory with favorable results. A wide variety of flagellate algae are acceptable as *Rangia* food depending on the salinity that the larvae are cultured in. Epifanio and his group have studied with success the algal species necessary to rear oysters through two years (Epifanio *et al.*, 1976). Several algal species are presently in culture in this laboratory and should provide ample ingredients for a successful copepod and molluscan larval food.

SwRI has discussed in several places the extra benefits possible from using additional species in Elutriate Bioassay procedural testing.

Specifically, our proposal is to use two of the WES proposed organisms, Daphnia pulex and Acartia tonsa, as principal test species and substitute Rangia cuneata larvae for Crassostrea. In addition, similar species to each of the three principals should be used in ancillary tests which will produce better correlation of test results through a broader range of sensitivity. Moina sp. is suggested as a cladoceran that is easily available, Pseudodiaptomus coronatus as a suitable copepod, and Crassostrea virginica as a backup molluscan species. Only experience in research can define the necessary repetition in bioassays needed for verification of the stability in results according to statistical principals. However, it is apparent through suggesting extra test species that the testing phase will be involved with more than the two organisms specifically mentioned in the RFP. The six species and the three time-dilution conditions indicated as a minimum from the basic disposal techniques equal 18 separate types of bioassay which may be run, each in several repetitions. The program designed is expected to handle this multiplicity in testing through use of stringent controls in equipment design and setup and careful regulation and chemical description of the test elutriate and dilution waters. By holding such variables to a minimum, successive tests with the same organism under different time-dilution schemes will be made simple matters of flow control. An optimistic assessment of the scheme proposes that with adequate input and organism controls, some prediction of later test results may be possible prior to the experiment. Should problems in Task III preclude the full level of testing proposed by SwRI, the experience gained in testing of Acartia and Rangia will still be adequate for the preparation of the Manual of Elutriate Bioassay.

For discussion purposes, SwRI will plan on initial tests of bioassays with the simplest time-dilution design and least problematical organism to be replicated five times. This will establish a relatively good variance in test responses. Later testing will be reduced to three replicates as results become more predictable. After establishment of some confidence in the test methodology through such experience with various species and time-dilution models, then a more comprehensive series of tests will be necessary for verification of the statistical methodology for inclusion in the manual prepared in Task IV. A selected Elutriate Bioassay type will be replicated ten times in order to establish the basis for manual test methodology verification.

While SwRI proposes the change in molluscan test organism and these increases in test species, we recognize that discussion and reconsideration with WES personnel may demonstrate the need for change in the planned research. The argument for stricter adherence to a proposed minimum number of species with greater statistical verification through repetition has merit.

E. Task VI - Manual Preparation and Final Report

The preparation of the Manual of Elutriate Bioassay will begin in the sixth month and be finished by the ninth month. In accordance with the requirements of the proposed research, this manual is to be simplified in style and content. Therefore, the actual writing will be more an exercise in determining the most important features of the procedural design and testing necessary for inclusion in the published procedure. Guidelines will be established for each time-dilution model and appropriate Elutriate Bioassay which will assist in determining the necessity of actual testing. This type of writing can benefit from input from the professional editorial staff at SwRI, and one of several available professionals will be asked to review and suggest revisions during preparation of the manual to better insure translation of scientific information into more easily understood directions for a standard procedure.

Along with preparation of the Manual of Elutriate Bioassay, the final report of overall activities will be initiated. It will consist of a complete explanation of the rationale for the bioassay design and procedural testing with particular attention paid to the various physical/ chemical controls instituted. The time-dilution models and their incorporation in practical dilution schemes will be explained. Organismal results will be reported according to accepted bioassay principles. This will involve complete description of results since the results of tests with no mortalities attributable to elutriate toxicity may have other benefit results as valuable as those which establish an LD 50.

The manual and final report will be presented at a contractor-arranged review meeting at the end of the tenth month, and any problems in manual design or test results will be resolved according to the provisions of the proposal. Every effort will be made to insure understanding of the progress of the research during each phase in order to prevent the development of problems in understanding the final results. SwRI is strongly committed to the hypothesis that an Elutriate Bioassay is a practical approach to the requirement for effects assessment of dredging activities according to Section 404 of Public Law 92-500.

The following reports will be prepared and forwarded to the Contracting Officer in accordance with each specified requirement. Reports submitted under this contract will reference and cite the contract number and identify the U. S. Army Engineer Waterways Experiment Station (WES) as the sponsoring agency. The report format content will be in accordance with the "Guide for Preparation of Waterways Experiment Station Contract Reports" dated August, 1974.

1. <u>Monthly Progress Report</u>

Southwest Research Institute will furnish three copies of a monthly progress report in letter form, briefly describing work performed during the preceding month and work planned for the next month. Specific areas of interest will include difficulties encountered during the reporting period and remedial action taken, progress in discussion sessions with WES personnel during literature review phases, and test formulation.

The report will also include any changes of personnel concerned with the project. Throughout the project, these reports will be submitted to the Contracting Officer by the tenth of the month following the period which is the subject of the report.

2. Draft Final Report

The Institute will submit to the Project Officer ten (10) copies of a draft report covering all items of work and services performed and the Manual of Elutriate Bioassay nine months after initiation of the project. A formal meeting for review of the research will be planned immediately between EEL personnel and the Contractor at WES. After the formal review meeting and return of the draft final report, the Institute will prepare and furnish the Contracting Officer an edited reproduction copy and five additional copies of the reproduction copy of the technical report within 335 days after the effective date of the contract.

IV. PROGRAM ORGANIZATION

The proposed research will be administered from the Houston Laboratories, Southwest Research Institute, under the direction of Dr. Herbert C. McKee with Dr. C. A. Bedinger, Jr. as principal investigator. Two on the staff at SwRI-Houston will be primarily responsible for system evaluation, design, testing, and manual preparation: Messrs. G. M. Hightower and Timothy L. Jones, respectively the Group Leaders of the Nekton and Zooplankton Sections. Technician assistance will be provided from their groups and will include individuals presently involved in the necessary tasks of organism collection, culture, and testing. Additional expertise in evaluation of data on time-dilution models will be provided by Dr. R. L. Bass, Manager, Hydro-Mechanical Systems, Division of Engineering Sciences, SwRI-San Antonio. Chemical analysis of elutriate preparations will be done in the SwRI-San Antonio laboratories of the Chemistry and Chemical Engineering Division's Analytical Chemistry and Biochemistry Section under the direction of Dr. Donald E. Johnson.

Qualifications of Principal Investigators

Three individuals will be primarily responsible for the completion of the proposed research. The team will be headed by C. A. Bedinger, Jr., Manager, Biological Research, SwRI-Houston, and will include G. M. Hightower, Nekton Studies Section Leader, and Timothy L. Jones, Zooplankton Studies Section Leader. The qualifications of these individuals important to the proposed work are given below.

Dr. Bedinger has acted as a biological coordinator for studies of the environmental impact of oyster shell dredging activities on the Texas coast. This research under sponsorship of the USACE, Galveston District Office, and the shell dredging industry in Texas offered a unique opportunity to observe dredging activities and their biological effects firsthand for over one year. Several monitoring and experimental activities provided significant information relative to the biological effects of silt from oyster dredges. The comprehensive nature of the overall study provided additional learning relative to the physical and geological effects of releasing dredged material in an open water environment. The principal investigator has also conducted several studies in general ecology of the brackish water clam, Rangia cuneata, for his dissertation research and is continuing those studies at present at SwRI under an internally sponsored research contract. The development of the clam from zygote to settled small clam has been followed and described. This research has elaborated on the work done by Hopkins et al. (1973) on this species under contract to WES. The results of these studies are a good understanding of the requirements for using Rangia as a laboratory test organism and its potential as an adaptable form for zooplankton research. Dr. Bedinger has directed several studies in short-term evaluation of the biological effects of contaminants in wastewater treatment systems and similar industrial situations using bioassay as a tool. He is responsible for research underway in this laboratory to investigate the most modern system design for use of zooplankton as a bioassay tool.

Mr. G. M. Hightower has established himself as a specialist in the effects of polluted water on nektonic species and aquarium health. Research in these areas has included the design of bioassay using flow-through and static tests of toxicity of several water soluble compounds extracted from petroleum bases. This research involved extensive design according to accepted statistical principles and therefore has acquainted Mr. Hightower with the necessary information to be used in establishing similar criteria in the proposed research. Recent research has used bioassay as a tool to identify problem areas in industrial water treatment through localization of a source of toxic materials in an industrial plant. Mr. Hightower is currently reviewing the various available designs and modifications for flow-through bioassay systems in an effort to establish the most contemporary system for wide application and long research life. Construction of such a system in a portable mode suitable for field establishment is a goal of SwRI and has insured that in-depth exploration of all the alternatives prior to construction has been done. Due to his continuing activities in bioassay and research at SwRI in evaluating the long-term effects of an electric power station, the nekton specialist has had ample experience in recognizing various disease and damage conditions in nektonic organisms. Maintenance of specimens subjected to such stresses has made him an expert in aquarium health and culture of aquatic species.

Mr. Timothy L. Jones is currently involved in research to assess the effects of entrainment and heated waters on zooplankton species. His efforts have utilized the most current techniques for evaluation of health of zooplankton and identification of estuarine species. He is primarily responsible for design of flow-through bioassay apparatus using zooplankton organisms as test species in this laboratory. Under his direction, Acartia tonsa and several other freshwater, estuarine, and marine zooplankters have been acclimated in this laboratory and several, including Acartia, have been cultured through several life cycles. This work has insured his learning of the requirements for rearing and maintaining zooplankton species.

V. BACKGROUND INFORMATION REGARDING QUALIFICATIONS OF SOUTHWEST RESEARCH INSTITUTE

A brief outline is presented here to describe the organization of Southwest Research Institute and identify some of the capabilities that would be utilized in the proposed project.

General

A nonprofit corporation founded in 1947, the Institute provides research, development, and evaluation services in a variety of engineering and scientific disciplines. During the Fiscal Year ending in September, 1975, a full-time staff of over 1300, including 450 professionals and the remainder technical and support personnel, conducted more than 500 applied-technology projects worth over $35 million. Its home office is in San Antonio, Texas; principal laboratories and offices occupy approximately 500,000 square feet of floor space on about 450 acres. Other SwRI laboratories and offices are located in Houston and Corpus Christi, Texas. Additional facilities and staff are available at the Institute's sister organization, Southwest Foundation for Research and Education (SFRE), established to conduct basic research in biomedical fields. The two organizations together comprise Southwest Research Center, a major asset to the scientific capability of the nation in both basic research and problem-solving applied research and development.

Southwest Research Institute presently includes 18 operating departments structured according to technical disciplines but administered to facilitate interdisciplinary activities. This interdisciplinary approach is further encouraged by technical councils that coordinate Institute activities in various broad fields of technology such as environmental management, materials, power sources, bioscience and bioengineering, and electronic systems. Supporting services are also provided, including computer services, instrument calibration, editorial and reproduction services, machine shop, library research, and others.

SwRI-Houston

The SwRI-Houston Laboratories, Division of Environmental Sciences and Engineering, have a 15-year history of air and water pollution research. The present staff includes three Ph. D's., six Master's, and about sixteen Bachelor's level degreed personnel. Several have direct experience with dredging activities, bioassay techniques, and laboratory equipment design. Bioassay has been an important part of the activities of the laboratory for a number of years and an integral part of the graduate training of the investigating team.

SwRI-Houston has recently done preliminary work in evaluating contemporary flow-through bioassay systems and in adapting such technology to zooplankton bioassay. As indicated in other sections of this proposal, these activities have included several aspects of collection, culture, testing, and consideration of test design which are an important part of the proposed research. An internally sponsored project, "Development of Contemporary Capability in Bioassay: Establish Flow-through Systems with Diluters and Laboratory Cultures of Important Plankton Species", is being initiated.

Environmental Programs

Since its inception, SwRI has been actively engaged in environmental studies such as air and water quality surveys, development and evaluation of methods of measurement, and development of waste treatment systems. In the last few years, these capabilities have been applied with increasing frequency to more comprehensive studies reflecting the increased public concern for environmental management, including major activities in vehicular emissions, environmental impact analysis, relationship of energy supplies to environmental control, and similar concerns. These comprehensive studies have also required the development of management techniques for integrating the capabilities of different disciplines into a project team to concurrently analyze scientific, engineering, ecological, sociological, economic, regulatory, and legal factors.

Recent Research Pertinent to the Proposed Studies

A selected list of recent research activities which have in their design studies pertinent to the needs of the proposed program follows.

An effect assessment study of proposed modifications to the Corpus Christi Ship Channel.

Biological analysis of Corpus Christi Bay water.

The effect of heavy metals and heavy metal compounds on plants and animals in an aquatic microcosm.

A comprehensive study of pesticide effects of biological compounds.

Analysis of herbicide residues in animal tissues.

Electron spin resonance studies of vegetation damage.

Study of environmental conditions in LaQuinta Channel.

A study of water and environmental data from selected sites in Nueces Bay.

Offshore ecology investigation

Biological effects of oil spills in bay waters.

Study of Four Corners Power Plant fly ash.

Evaluation and analysis of monitoring results.

Environmental monitoring program - Cedar Bayou Generating Station.

Monitoring program at new No. 3 Unit of Cedar Bayou Station.

A mathematical model of biological systems.

Siting study - Mississippi.

Site evaluation and environmental impact assessment.

Effects assessments studies, Corpus Christi Bay area.

Early diagnosis of pollution-induced plant damage.

Study on cause of fish malodors.

Experimental analysis of environmental effects of bay dredging.

Characterization of wastewater treatment system suspended solids at Orange, Texas, synthetic rubber plant.

Microscopic characterization of paper mill sewage waste.

Bioassay determination of an unknown toxicant in plant wastewater.

Support Facilities

The Institute Library contains approximately 19,000 volumes of books, 19,000 volumes of periodicals, and 50,000 documents and technical reports pertaining to all major fields of engineering, mathematics, chemistry, and physics. Documents are received on automatic distribution from a number of governmental and academic entities. Through these sources, other documents may be ordered as needed. SwRI-Houston has a growing library of approximately 5000 volumes and documents related to aquatic biology. In addition, excellent technical libraries at Rice University, the University of Houston, and the Houston Medical Center are available to the staff under existing arrangements.

Each project at Southwest Research Institute is established as a cost center. Complete financial reports on this project are provided by the Business System Group biweekly to the Project Manager. These financial status reports document in a timely manner project expenses so that the project may be supervised in such a manner as to insure maximum benefit from the resources available to accomplish the task.

The Computer Sciences Laboratory functions as a service and consulting organization throughout the Institute and is called upon to solve an extremely wide range of technical, scientific, and management information problems. The scientific applications staff have capabilities in statistics, numerical analysis, information theory, mechanics, and physics. The non-numerical applications staff have abilities in business management, systems development, computer systems evaluation, indexing, and information retrieval. The data processing equipment available to the Institute's Computer Laboratory is the most flexible and economical for their broad range of problems. A high-speed UNITECH 1 programmable user terminal remote to both a CDC 6500 and an IBM 370 gives the staff immediate access to two powerful computer systems.

For continuing use in environmental field studies, the Houston Laboratory has a minicomputer based data entry, storage, retrieval, and processing system. The system consists of two Datapoint minicomputers with 7.5 megabytes of online storage. Other peripherals include 9-track magnetic tape, cassette tapes, and 120 line per minute printer. The system can operate as a stand-alone computer or as a terminal emulator to the same large systems supporting the San Antonio computer facilities.

The staff of the SwRI Editorial and Publications Processing Unit comprise professionals and highly skilled technicians capable of performing in all of the skill areas necessary to publish scientific and technical publications, as well as the visual aids, reprints, and proceedings of technical symposia, conferences, and meetings. The Unit is especially equipped to process short-run, short-deadline publications. Its staff is a team of coordinators, editors, coldtype compositors, proofreaders, layout artists, illustrators, draftsmen, and photolithographic and bindery specialists geared to high-quality production and rapid dissemination of scientific and technical literature.

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APPENDIX

Professional record sheets of staff members who would be involved in the proposed research, or would be available for consultation.

JAMES H. BAKER
Senior Research Biologist
Environmental Science and Engineering Division

B.A. in Biology, Texas Christian University, 1962
M.S. in Biology, Texas Christian University, 1965
Ph.D. in Biology, University of Houston, 1975

A specialist in marine benthic organisms, Dr. Baker has experience in areas of applied zoology. After completing his master's thesis, he spent two and one-half years as a Research Associate on an industrial sponsored grant to Texas Christian University to study the effects of chemical effluent on the fauna of the lower Brazos and Colorado Rivers, Texas. Dr. Baker was in charge of the field collection and laboratory processing of biological specimens and data.

Nine months' work at the Smithsonian Oceanographic Sorting Center enabled Dr. Baker to gain expertise in identification of both benthos and zooplankton.

Additional experience was gained as a Research Associate with an EPA sponsored investigation of the effects of several different industrial effluents on the benthos of Trinity River, Fort Worth, Texas.

Since joining the Institute, Dr. Baker has been involved with a benthos study of the Galveston Bay area.

PROFESSIONAL CHRONOLOGY: Museum technician, Smithsonian Oceanographic Sorting Center, 1967; research associate, department of biology, Texas Christian University, 1968-70; administrative assistant, Institute for the Study of Cognitive Systems, Texas Christian University, 1969-70; administrative assistant, TCU Research Foundation, Texas Christian University, 1969-70; research associate, Coastal Ecosystems Management, Inc., 1970-1; research fellow, department of biology, University of Houston, 1970-3; Southwest Research Institute, 1973-(research biologist, 1973-5; senior research biologist, Houston Laboratories, 1975-).

Rev May/76

ROBERT L. BASS, III
Manager, Hydro-Mechanical Systems
Department of Mechanical Sciences

B.S. in Mechanical Engineering, University of Texas, 1964
M.S. in Mechanical Engineering, University of Texas, 1966
Ph.D. in Mechanical Engineering, University of Texas, 1968

Primary areas of professional interest for Dr. Bass are those involving fluid mechanics and heat transfer. This includes studies associated with gas dynamics, sub and supersonic aerodynamics, aero and hydroelasticity, cryogenic systems, fluid flow modeling, ducted flow systems, and gas flow instrumentation development.

Dr. Bass' academic pursuits included an experimental study of developing free turbulent shear layers in both sub and supersonic flow (M.S. Thesis) and a theoretical and experimental study of lift, drag, and flow-induced instabilities of flexible parawings operating at low subsonic speeds (Ph.D. Thesis). His industrial experience at DuPont included responsibility for improving the fluid dynamics of a unique process utilized for the manufacture of a polyethylene disposable material.

At Southwest Research Institute, Dr. Bass has engaged in aero and hydroelastic studies dealing with skirt flutter on air cushion vehicles, aerodynamic damping of vibrating helicopter rotors, unsteady loads and boundary layer activity on oscillating hydrofoils, and flow-induced vibrations in flexible bellows. He has conducted experimental programs using scale models to establish hydrodynamic and aerodynamic losses and flow characteristics in ducted systems for a variety of applications such as waterjet ducts for Surface Effect Ships and rocket propellant feedlines. In addition, he has experience with cryogenic systems through studies into the effects of heat transfer on the cryogenic flow in metal bellows and in studying impact loads associated with liquid dynamics in LNG cargo tanks. Dr. Bass has also engaged in studies of flow-measurement techniques and directed several programs which have resulted in the development of flow instrumentation suited for a wide range of applications.

PROFESSIONAL CHRONOLOGY: Production engineering assistant, Mobil Oil Company, 1963; teaching assistant and research assistant, department of mechanical engineering, University of Texas, 1964-8; research engineer, E.I. DuPont, Richmond, Virginia, 1968-70; Southwest Research Institute, 1970-(senior research engineer, 1970-3; manager, hydro-mechanical systems, department of mechanical sciences, 1973-).

Rev Nov/74

C. A. BEDINGER, JR.
Manager, Biological Research, Houston Laboratories
Environmental Science and Engineering Division

B. S. in Animal Science, Texas A&M University, 1964
M. A. in Biology, Sam Houston State University, 1967
Ph. D. in Zoology, Texas A&M University, 1974

Before joining the staff of Southwest Research Institute, Dr. Bedinger's educational training involved the study of parasites in fresh-water fish of East Texas and studies on the ecology of the brackish water clam Rangia cuneata in Trinity Bay, Texas. His Rangia work has involved quantitating biochemical constituents as indicators of condition and correlating with seasonal condition and ecological changes. He has worked with molluscan embryology, larval development, and symbionts. Dr. Bedinger was Biological Coordinator for a large multi-disciplinary study of the effects of oyster-shell dredging in the vicinity of the Aransas National Wildlife Refuge supported by the U. S. Army Corps of Engineers. He has authored several scientific publications and presented several papers. Dr. Bedinger has been involved with preparation and administration of scientific meetings at the regional, national, and international level. At Southwest Research Institute, his major area of research has been concerned with determining the effects of a steam electric generating station on a coastal estuary. He has assembled a staff with complete capability for biological research in aquatic environments.

PROFESSIONAL CHRONOLOGY: Graduate student and teaching assistant in biology, Sam Houston State University, 1965-7; teaching assistant, 1967-9 and National Science Foundation Trainee, 1969-71, Texas A&M University; biological coordinator, Texas A&M Research Foundation Projects 870-3 and 876-3, 1972-3; Southwest Research Institute-Houston, 1973-(senior research zoologist, 1973-4; manager, biological research, Houston Laboratories, 1974-).

Memberships: Beta Beta Beta Biological Honor Society, American Society of Parasitologists, The Society of the Sigma Xi, The Southwestern Association of Parasitologists, Gulf Estuarine Research Society, Texas Academy of Sciences.

Rev May 76

CLARENCE A. BOLDT, JR.
Manager, Chemical and Analytical Laboratory, Houston Laboratories
Environmental Science and Engineering Division

B.S. in Agriculture-Chemistry, Texas A&I College, 1950

Mr. Boldt has been extensively engaged in research and development for the past 20 years. His experience includes statistical and analytical techniques and the application of a wide variety of instrumentation used in air and water pollution. He has designed and developed new equipment and methods for sample analysis by gas chromatography. His experience includes the use of gas chromatography instruments, infrared spectrophotometers, hydrocarbon analyzer, carbon monoxide analyzer, carbon analyzer, continuous nitrogen dioxide analyzer, and ozone analyzer. Mr. Boldt has been associated with the instrument field to the extent of designing, manufacturing, and selling medical instruments in the capacity of vice president and general manager of an instrument company. His experience also includes working as a supervisor in the production control department of Continental Can Company. While employed by Southwest Research Institute, Mr. Boldt has participated in air and water pollution projects in a supervisory capacity. Some of his contributions to the Institute have included the basic design of an automatic refrigerated sequential sampler, a constant level device for bench-scale reactors, a multi-pH range electrophoresis apparatus, the basic design of a fluidized bed reactor for the removal of sulfur dioxide from stack gases, and carbon analyzer modifications. He is the coauthor of several published scientific papers and the coholder of a patent for the determination of inorganic carbon.

PROFESSIONAL CHRONOLOGY: Noncommissioned officer (crew chief), U.S. Army Air Corps, 1945-6; laboratory analyst, E. I. du Pont, 1951-62; vice president and general manager, R. L. Faley and Associates, Inc., 1962-3; production schedule coordinator, Continental Can Company, 1963-4; Southwest Research Institute, 1964-(research chemist, 1964-73; senior research chemist, 1973-4; manager, chemical and analytical laboratory, Houston Laboratories, 1974-).

Rev May/76

ARTHUR W. BUSCH
Vice President
Environmental Affairs

B.S., in Civil Engineering, Texas Tech University, 1950.
S.M., in Sanitary Engineering, Massachusetts Institute of Technology, 1952.
Distinguished Engineer Award, Texas Tech University, 1972.

As Vice President for Environmental Affairs at Southwest Research Institute, Mr. Busch is responsible for coordination of all Institute programs related to environmental matters. Prior to joining the staff, Mr. Busch was on leave from Rice University to serve as Regional Administrator, U.S. Environmental Protection Agency, Region VI. He was responsible for all programs in air, water, solid wastes, radiation, pesticides, and noise in Texas, New Mexico, Oklahoma, Arkansas, and Louisiana, and had 320 employees under his supervision. Mr. Busch also served as Chairman of the Southwest Federal Regional Council, a Presidential Appointment in 1974. He was responsible for coordination of the nine major federal granting agencies: Environmental Protection Agency, Law Enforcement Assistance Administration, Department of Transportation, Office of Economic Opportunity, Department of Labor, Department of Health, Education and Welfare, Department of Agriculture and Department of Interior, with the objective of more effective implementation of New Federalism. Both positions were of high public visibility, requiring contact with all elected officials in the five-state region; national, state, and local. Mr. Busch is the author of over 60 papers and one technical monograph and is editor of numerous conference proceedings. During his 20 years at Rice University, Mr. Busch served as Professor and Chairman of the Environmental Science and Engineering Department. He set up the graduate sanitary engineering curriculum, developed laboratory and research programs, and was a consultant to industry and government.

PROFESSIONAL CHRONOLOGY: 1944-46, Army of the United States, Infantry and Engineer Aviation Battalion, Sergeant-Major, Service in Philippine Islands; 1947-50, Student, Department of Civil Engineering, Texas Tech. University; 1950, Assistant to Design Engineer, International Minerals and Chemical Corporation, Carlsbad, New Mexico; 1950-52, Graduate student and Research Assistant, Department of Civil and Sanitary Engineering, Massachusetts Institute of Technology; 1952-55, Assistant to Director of Research and Development, Infilco, Inc., Tucson, Arizona; 1955-61, Assistant Professor of Civil Engineering, Rice University; 1961-64, Associate Professor of Environmental Engineering, Department of Chemical Engineering, Rice University, Director of the Program of Graduate Study and Research in Environmental Engineering; 1964-67, Professor of Environmental Engineering and Chairman, Department of Environmental Science and Engineering, Rice University; 1970-71, Professor of Environmental Engineering, Rice University; 1972-75, On leave from Rice University to serve as Regional Administrator, U.S. Environmental Protection Agency, Region VI.; Feb, 1975, Vice President for Environmental Affairs, Southwest Research Institute.

HONORS AND MEMBERSHIPS:

Sigma Xi, Tau Beta Pi, Cosmos Club, American Men of Science, various Who's Who Listings.
Recipient Environmental Division Award, National American Institute of Chemical Engineers, 1973.
Diplomate American Academy of Environmental Engineers by Distinction, 1973.
Distinguished Engineer Award, Texas Tech. University, 1972.
Appointed to President's Air Quality Advisory Board, July, 1971.
Co-recipient, Harrison Prescott Eddy Medal for Noteworthy Research, Water Pollution Control Federation, 1961.
Certificate of Merit, American Chemical Society Division of Water Chemistry, 1952.
Member: American Chemical Society, Water Pollution Control Federation, American Institute of Chemical Engineers.
Registered Professional Engineer in Texas.
National Director and Member of Executive Committee, Environmental Division, American Institute of Chemical Engineers, 1970-71.

March, 1975

RALPH E. CHILDERS
Staff Engineer
Environmental Science and Engineering Division

B.S. in Chemical Engineering, University of Cincinnati Evening College, 1962
Graduate Studies, University of Cincinnati Evening College

Mr. Childers, a registered professional engineer, has broad experience in the fields of chemical engineering, mathematics, statistics, and computer technology. He has had research and development experience in water and air pollution control, desalination cost engineering, rare earth separation, inedible fats and oils processing, and agricultural residues utilization. During his association with the Institute, Mr. Childers has demonstrated capabilities as a mathematician and as a computer professional in process simulation, mathematical modeling, scientific programming, and data base administration. He is a data processing specialist and is familiar with experiment design and statistical techniques. He has designed and implemented data base management systems using minicomputer hardware. Mr. Childers has been engaged in the technical direction of the collaborative testing of air pollution measurement methods. He has also been active in the field of thermal pollution, and has developed novel data collection and processing methods. He has been instrumental in the development of desalination process cost methodology. He has managed other projects involving dissolved oxygen characteristics of cooling water supplies; mathematical modeling of diffusion, heat transfer, and fluid flow; and cooling pond performance. Prior to joining the Institute, Mr. Childers served as an industrial waste chemical engineer for the City of Cincinnati. He has managed the analytical laboratory and directed research and development efforts. As chief chemist for Kentucky Chemical Industries, he was responsible for processing and quality control of inedible animal fats. While with National Lead Company of Ohio, Mr. Childers was involved in rare earth chemistry, and during his service in the USDA, he was primarily engaged in absorption spectroscopy.

PROFESSIONAL CHRONOLOGY: Research assistant, Northern Regional Research Laboratory (USDA), Peoria, Illinois, 1946-51 and 1954; self-employed, 1951-4; chemist, National Lead Company of Ohio, Cincinnati, Ohio, 1954-5; chief chemist, Kentucky Chemical Industries, Cincinnati, Ohio, 1955-7; industrial waste chemical engineer, City of Cincinnati–Water Pollution Control Division, 1957-65; Southwest Research Institute, 1965-(senior research engineer, 1965-71; staff engineer, Houston Laboratories, 1971-).

Rev May 76

GLENN M. HIGHTOWER
Research Zoologist
Environmental Science and Engineering Division

B.S. in Zoology, Texas A&M University, 1971
M.S. in Biology, Texas A&M University, 1973

A professional research zoologist specializing in marine environmental studies, Mr. Hightower has a background of experience in many different marine ecological studies. He studied larval growth and development of the brackish water clam Rangia cuneata, and also served as a field biologist and fish and crustacean taxonomist on an ecological project to evaluate the effects of shellfish dredging in San Antonio Bay on the Texas coast. In the latter study, he was responsible for all of the marine fish taxonomic identification and for collection of marine organisms in the estuary. While a graduate student at Texas A&M University, he also worked on a study of the effects of petroleum on marine organisms. This work included extensive laboratory studies to measure the effects of four different oils on the metabolic activities of estuarine fish, to determine the possible effects of oil on fish found in coastal estuaries. Since joining the Institute, he has been involved in determining the effect of a power generation station on a coastal estuary. This work includes sample collection and analysis, to identify marine fish and crustaceans and to evaluate damage due to the power plant or other causes.

PROFESSIONAL CHRONOLOGY: Marine fish taxonomist on a grant from the Corps of Engineers and shellfish dredging companies, February-September, 1972; marine fish physiologist on a grant from the American Petroleum Institute, 1972-3; Southwest Research Institute, 1973-(research zoologist, Houston Laboratories, 1973-).

Memberships: Phi Sigma Society, Beta Rho Chapter, honorary biological society; Gulf Estuarine Research Society; American Fisheries Society-Certified Fisheries Scientist.

Rev May 76

JAMES T. (TOM) IVY
Research Biologist
Environmental Science and Engineering Division

B. S. in Botany, Texas A&M University, 1969
M. S. in Botany, Texas A&M University, 1972

A specialist in algal studies, Mr. Ivy has experience in areas of applied phycology. In work on his master's thesis, "Eutrophication Potential of Secondary and Tertiary Wastewater Effluents," he investigated the effect on algal growth of phosphate removal by a $1.5-million experimental tertiary waste treatment plant at Dallas, Texas. These studies were conducted in the laboratory and in a two-stage algal lagoon system. The object of this research was to establish a level of phosphate removal that would prevent objectionable growths of algae in a reservoir which would receive a tertiarily treated effluent. Mr. Ivy has conducted algal bioassays in the investigation of the effects of toxic materials on algal growth rates. In this connection, he has acted as a consultant to determine the cause of algal mortality in a lagoon system which was being used to treat industrial wastes. As an independent investigator, Mr. Ivy has conducted studies on microwave-algal interactions with the objective of devising an algae harvesting system. Since joining the Institute, he has acted as phytoplankton group leader in an ecological study of Galveston Bay.

PROFESSIONAL CHRONOLOGY: United States Army Security Agency, 1961-5; research associate, environmental engineering division, civil engineering department, Texas A&M University, 1970-2; Southwest Research Institute, 1973-(research biologist, Houston Laboratories, 1973-).

Memberships: Phycological Society of America.

Rev May 76

DONALD E. JOHNSON
Manager, Analytical & Biochemistry Section
Division of Chemistry and Chemical Engineering

B.S. in Agriculture, Texas A&M University, 1957
M.S. in Biochemistry, Texas A&M University, 1959
Ph.D. in Biochemistry, Tufts University School of Medicine, 1962

Dr. Johnson's academic training is in both medical and agricultural biochemistry. His graduate research was directed at the development of analytical procedures for use in biomedical applications. At Southwest Research Institute, Dr. Johnson has directed numerous research projects aimed at the development and application of analytical procedures to the analysis of inorganic and organic substances present in trace quantities. The research objectives of these projects have involved various aspects of environmental sciences, including monitoring body burdens and environments, toxicity evaluations, and epidemiologic studies. The toxicological projects have included acute, sub-acute and chronic evaluations via oral, dermal, intra-muscular and inhalation routes of exposure. Data on the carcinogenic activity, pharmacokinetics, tissue distribution, and metabolism of the test substances were collected in various animal species, including man.

Dr. Johnson's most recent research is directed at environmental epidemiology studies of trace metals, viral and bacterial pathogens and pesticides from mobile and stationary sources. This research involves the design of surveys of populations for body burdens and collection of health effects information. These surveys have been conducted in occupationally exposed populations and the general population and required the sampling of age groups from infants to the elderly.

PROFESSIONAL CHRONOLOGY: Department of biochemistry, Texas A&M University, 1958-9; department of biochemistry, Tufts University School of Medicine, 1959-62; Southwest Research Institute, 1962-(associate biochemist, 1962-3; senior biochemist, department of chemistry and chemical engineering, 1963-4; manager, analytical and biochemistry section, department of physical and biological sciences, 1964-8; manager, analytical and biochemistry section, division of chemistry and chemical engineering, 1968-).

Memberships: New York Academy of Sciences

Rev Feb/75

TIMOTHY L. JONES
Research Biologist
Environmental Science and Engineering Division

B.S. in Biology, Stephen F. Austin State University, 1970
M.S. in Wildlife and Fisheries Sciences, Texas A&M University, 1975

After receiving his B.S. at Stephen F. Austin, Mr. Jones worked from September, 1970, until May, 1973, as Graduate Research Assistant at Texas A&M University, Department of Wildlife and Fisheries Sciences. Research for his master's thesis consisted of 17 months (January, 1971 - May, 1972) of sampling meroplankton (temporary plankton - larval fishes and crustaceans) in the intake and discharge areas of Houston Lighting & Power Company's Cedar Bayou Electric Power Station at Baytown, Texas, the primary objective being to determine the effect of heated effluent on these organisms. During this time, he became very familiar with many of the larval fishes and crustaceans as well as some of the larger permanent zooplankton present in the Trinity Bay area. Since joining Southwest Research Institute, he has been involved in sampling and identification of zooplankton in the intake and discharge areas of a power generating station on a coastal estuary.

PROFESSIONAL CHRONOLOGY: Graduate research assistant, Department of Wildlife and Fisheries Sciences, Texas A&M University, 1970-3; Southwest Research Institute, 1973-(research biologist, Houston Laboratories, 1973-).

Rev May 76

KAY T. KIMBALL
Senior Technician
Environmental Science and Engineering Division

B.S. in Biology, University of Houston, 1970
M.S. in Biology, University of Houston, 1976

Ms. Kimball's graduate training involved studies in geographic variation of mating behavior in the housefly, Musca domestica L., and morphological variation among geographic strains of the species. Using univariate and multivariate statistical procedures, geographic morphometric variation was described. The expression of this genetic variation in mating behavior and environmental selective agents was determined. Ms. Kimball's other research at the University of Houston included studies on the temporal and spatial distribution of insect species in a grassland community. While at Southwest Research Institute, she has been involved in identification of zooplankton and data preparation for the zooplankton section in a larger research effort to collect and identify the flora and fauna in the estuarine environment of the Texas coast. Her statistical analysis of various sampling and subsampling procedures has contributed to significant reduction in sampling costs for nekton and benthos. She has also done quality control analysis for the zooplankton, phytoplankton, nekton, and chemistry sections. She is the author of several scientific publications.

PROFESSIONAL CHRONOLOGY: Graduate student and teaching assistant in biology, University of Houston, 1970-1; National Science Foundation trainee, 1971-2; National Science Foundation summer trainee, 1972; Southwest Research Institute, 1973-(technician, 1973; senior technician, Houston Laboratories, 1973-).

Memberships: Phi Kappa Phi honor society, Alpha Epsilon Delta honor society, American Society of Naturalists, Society for the Study of Evolution.

Rev May 76

RUDY MAREK, JR.
Manager, Field Operations, Houston Laboratories
Environmental Science and Engineering Division

B.S. in Chemistry, Southwest Texas State University, 1954

A specialist in chemical and biological studies relating to air and water pollution, Mr. Marek has had over 20 years of experience in field and laboratory studies in this area. During his 12 years with the Texas Parks and Wildlife Department, Mr. Marek was responsible for all studies evaluating the effects of pollution on marine, aquatic, and other forms of wildlife. He specialized in conducting bio-assay studies, both in the field and in the laboratory. Following such studies, he consulted with industry and governmental agencies on waste treatment methods to alleviate environmental problems.

Mr. Marek was also an official observer and adviser for the Texas Parks and wildlife on offshore and deep sea waste disposal studies conducted by Texas A&M University for industries to trace the effects of industrial wastes on marine and benthic organisms. These studies also involved monitoring of dispersion rates, waste concentrations, gulf currents, and other hydrological and meteorological factors.

Since joining the Institute staff, Mr. Marek has conducted a number of studies on air and water pollution projects for various industries, NASA, EPA, and other sponsors. This work includes both area-wide measurements of ambient air and water quality, as well as stack sampling and effluent measurements to determine compliance with governmental regulations. Studies of the effects of pollution include damage to vegetation as a result of air pollution, and changes in water quality in both freshwater lakes and streams and coastal estuaries. Water quality studies have included such diverse tasks as measuring acute and chronic toxicity of chemicals and waste water on aquatic organisms, effects of waste discharge on fish migrations, malodorous compounds causing tainting of fish flesh, and measurements of other undesirable effects. Another unique study Mr. Marek has undertaken involved body wastes as a means of potable water supply on spacecraft missions of long durations.

PROFESSIONAL CHRONOLOGY: X-ray specialist, U. S. Air Force, Anchorage, Alaska, 1947-50; chief chemist, Texas Foamed Plastics Corp., Gonzales, Texas, 1956-7; senior chemist, Texas State Parks and Wildlife Department, 1954-65; Southwest Research Institute, 1965-(assistant research chemist, 1965-8; research chemist, 1968-73; senior research chemist, 1973-4; manager, field operations, Houston Laboratories, 1974-).

Rev May 76

HERBERT C. McKEE
Director, Houston Laboratories
Environmental Science and Engineering Division

B.S. in Chemistry and Mathematics, Muskingum College, 1942
M.S. in Chemical Engineering, Ohio State University, 1947
Ph.D. in Chemical Engineering, Ohio State University, 1949

A registered professional engineer in Ohio and Texas, Dr. McKee has extensive experience in the methods and management of industrial research, particularly in the fields of air and water pollution, precision analytical methods, process development, distillation, and corrosion. At the OSU Research Foundation, he conducted hygroscopicity studies of fertilizer materials and designed and operated pilot plants for manufacturing inorganic chemicals. Later, as an industrial chemical engineer, he contributed to the development of processes for producing organic chemicals. Since joining the SwRI staff, he has planned and supervised several long-range programs in air and water pollution, marine biology, biochemistry, and development of special analytical methods. He has directed several major projects including a large-scale urban air pollution survey (Houston, Texas), evaluation and testing of methods to measure atmospheric contaminants, evaluation of equipment for protection against airborne toxic and corrosive agents, development of synthetic lubricants, and the design of bench-scale pilot plants. Dr. McKee is the author (coauthor) of numerous technical papers in his special fields.

PROFESSIONAL CHRONOLOGY: Commissioned officer, USA Air Corps Armament Laboratory, Wright-Patterson, 1944-6; research associate, Ohio State University Research Foundation, 1948-50; chemical engineer, Austin Laboratories, Jefferson Chemical Company, 1950-3; Southwest Research Institute, 1953-(senior chemical engineer, 1953-7; manager, air pollution research, 1957-60; section manager, industrial pollution and analytical research, 1960-1; assistant director, department of chemistry and chemical engineering, 1961-74, (assigned to SwRI-Houston, 1962); director, Houston Laboratories, 1974-).

Memberships: American Chemical Society, American Institute of Chemical Engineers, Air Pollution Control Association, American Academy of Environmental Engineers, American Society for Testing and Materials, Scientific Research Society of America, American Industrial Hygiene Association (Gulf Coast Section), Chairman, Texas Air Control Board (1966-73), Member, Governor's Energy Advisory Council (1973-6), Member, Advisory Committee to Governor's Energy Advisory Council (1976-).

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